

GAO

Report to the Chairman, Committee on
the Budget, House of Representatives

January 1998

DEPARTMENT OF
ENERGY

Fossil Energy
Programs



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Resources, Community, and
Economic Development Division

B-278987

January 30, 1998

The Honorable John R. Kasich
Chairman, Committee on the Budget
House of Representatives

Dear Mr. Chairman:

The Department of Energy's (DOE) fiscal year 1998 appropriations provide about \$362 million for the Fossil Energy Research and Development (R&D) Program and rescinds about \$101 million of the \$2.4 billion in appropriations for the related Clean Coal Technology Demonstration Program.¹ These two programs are managed by DOE's Office of Fossil Energy to develop and demonstrate advanced technologies for producing and using fossil fuels through federally funded projects and cost-shared partnerships with industries. As agreed with your office, this report provides information on (1) the R&D goals and technologies being developed by the Fossil Energy R&D and Clean Coal Technology Demonstration programs, (2) the level of funding committed to R&D activities within these programs in fiscal years 1996 through 1998, and (3) the companies receiving R&D awards (during these fiscal years) in which the government contributed more than \$1 million.²

We categorized R&D activities as basic research, applied research, development, and demonstration. Appendix I provides the definitions used in this report for these R&D phases.

Results in Brief

DOE's overall R&D goal for its Fossil Energy R&D and Clean Coal Technology Demonstration programs is to improve the efficiency and environmental performance of current methods for producing and using coal, natural gas, and petroleum. For coal, this improvement translates into R&D efforts by both programs to develop and demonstrate technologies that efficiently remove potential environmental pollutants from coal prior to its use.

¹Between 1985 and 1992, the Congress passed several appropriation acts that provided \$2.7 billion for the Clean Coal Technology Demonstration Program that would remain available until the funds were expended, rescinded, or sequestered. These funds have been reduced through rescissions and sequestrations, including the fiscal year 1998 rescission, to about \$2.3 billion. DOE officials can continue to use remaining funds to complete ongoing or new projects. During fiscal year 1998, DOE intends to obligate (i.e., commit to spend) about \$220 million.

²Unless stated otherwise, this report discusses funding in terms of actual and estimated obligations, which are funds that DOE has committed or will commit to spend during a fiscal year. DOE generally commits to spend funds by awarding contracts and cooperative agreements or agreeing to fund specific activities that are included under such agreements.

Improvement also means the development of technologies that either generate electricity from coal more efficiently than current technologies or that can generate electricity from liquids and gases derived from coal. For natural gas and petroleum, DOE is focusing its efforts on improving drilling, storage, transportation, and combustion technologies and processes associated with locating, extracting, and using the resources.

DOE obligated or plans to obligate about \$1.3 billion for R&D activities sponsored by the two programs during fiscal years 1996 through 1998.³ The Fossil Energy R&D Program provides \$856 million, \$743 million of which has been or will be spent on activities in the applied research and development phases of R&D; the remainder will be spent for basic research. The Clean Coal Technology Demonstration Program accounts for about \$417 million of the \$1.3 billion in obligations. Because the program concentrates its efforts on technologies that have completed laboratory and field testing, the program obligated funds exclusively on technologies in the demonstration phase of R&D. In addition, DOE obligated or plans to obligate about \$307 million for the management of the programs and other non-R&D activities.

For the 3 fiscal years examined, DOE's fossil energy programs made or continued 162 R&D contracts and other types of assistance in which the government committed to spend more than \$1 million. These procurement awards involved 112 companies and other nonfederal participants. The largest of these awards generally went to companies participating in the Clean Coal Technology Demonstration Program. Many of these awards were for projects that spanned several years and were partly funded by the companies.

Background

The Fossil Energy R&D Program and the Clean Coal Technology Demonstration Program support the research, development, and demonstration of a variety of coal, natural gas, and petroleum technologies. The Fossil Energy R&D Program, which has been part of DOE since it was created in the 1970s, supports R&D which DOE expects to lead to technologies that will be used by electric utilities and other industries. If the program is successful in developing commercially viable technologies, DOE expects that these technologies will be significantly more efficient and environmentally acceptable than fossil fuel burning technologies used

³The data provided in this report regarding funds DOE obligated or plans to obligate for the Fossil Energy R&D and Clean Coal Technology Demonstration programs are as of December 1997.

today. The program includes a broad spectrum of basic and applied research and development, some of which is cofunded by industry.

The Clean Coal Technology Program, which was authorized in 1984, is a partnership between government and industry for sharing the costs of commercial-scale projects that DOE believes can be more efficient than current coal technologies. The Congress has appropriated a total of \$2.3 billion for the program, which has been implemented through a series of competitive solicitations of projects. Each project is carried out and funded under a cooperative agreement between DOE and the project's sponsor. DOE funds up to 50 percent of a project's cost, and the project's sponsor and other nonfederal participants fund the balance.

Goals and Technologies Supported by DOE's Fossil Energy Programs

For program management and budget purposes, DOE has organized its Fossil Energy R&D Program into five major R&D areas, several of which are further divided into subprograms. The general goal of work in these areas—together with the Clean Coal Technology Demonstration Program—is to improve the utilization of fossil fuels by improving facets of the production, delivery, and/or use of coal, natural gas, and petroleum. Table 1 summarizes the subprograms' goals and provides examples of technologies addressed by these major program areas. Appendix II presents additional details on goals and technologies for activities within the subprograms.

Table 1: Goals and Technologies of DOE's Fossil Energy R&D Program and Clean Coal Technology Demonstration Program

| Program | Subprograms | Goals | Technologies |
|-------------------------------------|---|--|--|
| Coal | Advanced clean fuel research; advanced clean/efficient power systems; advanced research and technology development | Develop highly efficient integrated coal combustion technologies. | Chemical cleaning processes, fluidized bed combustion, Fischer-Tropsch liquefaction |
| Gas | Natural gas research; fuel cells | Improve exploration and production technologies, gas turbines, and chemical fuel cell systems. | Reservoirs modeling, corrosion resistant materials, and solid oxide fuel cell system |
| Petroleum | Oil technology | Produce economically, hard to reach oil and improved refinery technologies. | Microbes, thermal, and other oil extraction techniques; improved environmental compliance technologies |
| Cooperative R&D | None | Improve basic scientific information available on the use of fossil fuels. | Variety of collaborative fossil energy R&D activities |
| Mining | Materials | Develop extended life and better performance for material in corrosive and high-temperature applications. | Advanced processes for producing metal alloys |
| Clean Coal Technology Demonstration | Advanced electric power generation systems, environmental control devices, coal processing for clean fuels, and industrial applications | Develop more efficient and environmentally acceptable coal technologies for electric utilities and industry. | Low nitrogen oxide coal emissions systems, coal gasification or fluidized bed combustion systems integrated into electric power plants |

Source: Developed by GAO using DOE's data.

Fiscal Years 1996 Through 1998 Funding for DOE's Fossil Energy R&D and Clean Coal Technology Demonstration Programs

As of December 1997, DOE obligated or planned to obligate about \$1.3 billion (or about 75 percent) of its fiscal years 1996 through 1998 funding on R&D activities within the Fossil Energy R&D and Clean Coal Technology Demonstration programs. (See table 2.) The remaining funds were obligated or were to be obligated for environmental restoration, program management, and other non-R&D activities.

Table 2: Summary of Fiscal Years 1996 Through 1998 Obligations for R&D and Non-R&D Programs Within Two of DOE's Fossil Energy Programs

| Dollars in millions | | | | |
|-------------------------------------|----------------|----------------|----------------|-------------------|
| Activity/program area | FY 1996 | FY 1997 | FY 1998 | Total |
| Research and Development | | | | |
| Fossil Energy R&D | \$296.2 | \$286.2 | \$273.7 | \$856.1 |
| Clean Coal Technology Demonstration | 30.6 | 182.2 | 204.1 | 416.9 |
| Subtotal | 326.8 | 468.4 | 477.8 | \$ 1,273.0 |
| Non-Research and Development | | | | |
| Fossil Energy R&D | 85.3 | 85.8 | 87.6 | 258.7 |
| Clean Coal Technology Demonstration | 16.0 | 16.0 | 15.9 | 47.9 |
| Subtotal | 101.3 | 101.8 | 103.5 | 306.6 |
| Total | \$428.1 | \$570.2 | \$581.3 | \$1,579.6 |

Source: Developed by GAO using DOE's data.

Fiscal Years 1996 Through 1998 Funding for R&D Activities

As of December 1997, DOE obligated or planned to obligate about \$1.3 billion for fiscal years 1996 through 1998 R&D activities sponsored by the two programs. About \$743 million (or about 87 percent) of the Fossil Energy R&D Program's funding has been or will be spent on activities in the applied research and development phases of R&D. (See table 3.) Projects in these phases are in the laboratory for research or small-scale testing and are not ready to be tested under commercial operating conditions. About \$113 million (or about 13 percent) of the program's funding has been or will be spent on basic research. In addition, about \$417 million has been or will be spent by the Clean Coal Technology Demonstration Program on projects to demonstrate the commercial feasibility of technologies. Projects in this phase are closest to the marketplace in terms of eventual commercialization.

Table 3: Estimated Obligations by Research Phase for R&D Activities Within Two of DOE's Programs, Fiscal Years 1996 Through 1998

Dollars in millions

| Program | Basic research | Applied research | Development | Demonstration | Total |
|-------------------------------------|----------------|------------------|----------------|---------------|----------------|
| Fossil Energy R&D | | | | | |
| Coal | \$59.9 | \$167.1 | \$102.2 | 0 | \$329.2 |
| Gas | 25.0 | 173.0 | 144.9 | 0 | 342.9 |
| Petroleum | 7.7 | 72.7 | 70.0 | 0 | 150.4 |
| Cooperative R&D | 4.4 | 4.4 | 8.8 | 0 | 17.6 |
| Mining R&D | 16.0 | 0 | 0 | 0 | 16.0 |
| Total | \$113.0 | \$417.2 | \$325.9 | 0 | \$856.1 |
| Clean Coal Technology Demonstration | 0 | 0 | 0 | \$416.9 | \$416.9 |

Source: Developed by GAO using DOE's data.

Appendixes III and IV have a comprehensive listing of R&D funding by phase for each Fossil Energy R&D subprogram and activity and for the Clean Coal Technology Demonstration Program, respectively, for fiscal years 1996 through 1998.

Fiscal Years 1996 Through 1998 Funding for Non-R&D Activities

DOE obligated or plans to obligate an additional \$307 million to manage the programs and other non-R&D activities in fiscal years 1996 through 1998. Of these funds, about \$250 million (or about 81 percent) is or will be obligated for program direction and management support. (See table 4.) Program direction and management support includes funding for salaries and benefits, travel, administrative services, and other related activities. Other non-R&D funds will be used to improve the physical infrastructure at DOE research sites, clean up environmental damage caused by DOE's activities at its research sites, and promote coal technology export programs.

A description of the non-R&D activities funded by the two programs is included in appendix V.

Table 4: Budget Obligations for Non-R&D Programs Within Two Energy Programs, Fiscal Years 1996 Through 1998

| Dollars in millions | | | | |
|--|--------------------|---------------|---------------|----------------|
| Program | Budget obligations | | | Total |
| | FY 1996 | FY 1997 | FY 1998 | |
| Fossil Energy R&D | | | | |
| Program direction and management support | \$65.6 | \$68.7 | \$66.1 | \$200.4 |
| Environmental restoration | 14.4 | 12.6 | 13.3 | 40.3 |
| Coal ^a | 0 | 0 | 3.3 | 3.3 |
| Fuels Program | 2.4 | 2.4 | 2.2 | 7.0 |
| Plant and capital equipment | 2.9 | 2.1 | 2.7 | 7.7 |
| Total | \$ 85.3 | \$85.8 | \$87.6 | \$258.7 |
| Clean Coal Technology Demonstration | | | | |
| Program direction and management support | \$16 | \$16 | \$15.9 | \$47.9 |

^aThese funds are used for coal technology export, support of international activities, and grants to colleges and universities, as discussed in app. V.

Source: Developed by GAO using DOE's data.

Companies Receiving Funds During Fiscal Years 1996 Through 1998

DOE uses contracts, grants, and cooperative agreements to encourage industry participation and cost-sharing in R&D activities. During fiscal years 1996 and 1997 and fiscal year 1998 through December 16, 1997, 112 companies received 162 awards to conduct R&D activities.

The Clean Coal Technology Demonstration Program made the largest award, which was for \$219 million. Other awards made by the program ranged from \$490,000 to \$183 million. (See table 5 for a list of the program's 10 largest awards.) Many of the active awards are for projects that span several years and are being partly matched by the companies. Because many of the current projects involve the demonstration of technologies at large electric power plants, the government's share of the cost of these projects is generally more expensive than research activities funded by the Fossil Energy R&D Program.

Table 5: Projects and Companies Associated With the Most Costly Demonstration Projects

Dollars in millions

| Principal participant^a | Description of project | Typical non-DOE team member^b | Government share of costs | Industry share of costs |
|---|---|--|----------------------------------|--------------------------------|
| Wabash River Coal Gasification Repowering Project Joint Venture | Wabash River Coal Gasification Repowering Project | PSI Energy, Inc., Destec Energy, Inc. | \$219.1 | \$219.1 |
| Clean Energy Partners, L.P. | Clean Energy Demonstration Project (fuel cell) | Fuel Cell Engineering Corp., Electric Power Research Institute | \$183.3 | \$657.8 |
| Tampa Electric Company | Tampa Electric Integrated Gasification Combined Cycle Project | Texaco Development Corp., General Electric Company | \$171.0 | \$172.5 |
| Sierra Pacific Power Company | Pinion Pine Integrated Gasification Combined Cycle Power Project | Foster Wheeler USA Corp., The M. W. Kellogg Company | \$168 | \$167.9 |
| CPICOR Management Company, L.L.C. | Clean Power From Integrated Coal/Ore Reduction (CPICOR) | Geneva Steel Company, Air Products and Chemicals, Inc. | \$149.5 | \$916.3 |
| Alaska Industrial Development and Export Authority | Healy Clean Coal Project | Golden Valley Electric Assn., TRW, Inc. | \$117.3 | \$124.8 |
| City of Lakeland, Fla. | McIntosh Unit 4B Topped Pressurized Bubbling Fluidized-Bed Combustion Demonstration Project | Foster Wheeler Energy Corp., Westinghouse Electric Corp. | \$109.2 | \$109.5 |
| City of Lakeland, Fla. | McIntosh Unit 4A Bubbling Fluidized-Bed Combustion Demonstration Project | Foster Wheeler Energy Corp., Westinghouse Electric Corp. | \$93.3 | \$93.3 |
| Air Products Liquid Phase Conversion Company, L.P. | Liquid Phase Methanol Demonstration | Air Products and Chemicals Inc., Eastman Chemical Company | \$92.7 | \$121.0 |
| York County Energy Partners, L.P. | Advanced Circulating Fluidized-Bed Demonstration Project | Foster Wheeler Energy Corp. | \$74.7 | \$304.9 |

^aCompanies receiving awards from DOE may represent or lead teams of multiple contractors. In these cases, the lead company may divide the government's share of costs among team members.

^bAll partners have not been listed.

Source: Developed by GAO using DOE's data.

Within the Fossil Energy R&D Program, DOE's 10 largest awards for R&D activities ranged from \$29 million to \$128 million.⁴ (See table 6.) Six of these companies received multiple awards. Westinghouse Electric Corporation received four awards; the total government share of these awards was \$296.4 million. Each company provided some matching funds.

Table 6: Projects and Companies Associated With the Most Costly R&D Projects Active During Fiscal Years 1996 Through 1998

Dollars in millions

| Company ^a | Number of awards | Government share of costs | Industry share of costs | Description of largest award |
|----------------------------------|------------------|---------------------------|-------------------------|---|
| Westinghouse Electric Corp. | 4 | \$296.4 | \$340.2 | Utility advanced turbine systems |
| Foster Wheeler Development Corp. | 1 | \$127.9 | \$71.6 | Coal-fired high-performance power systems |
| General Electric Co. | 2 | \$121.1 | \$263.7 | Utility advanced turbine systems |
| Energy Research Corp. | 1 | \$101.7 | \$39.7 | Molten carbonate fuel cells |
| United Technologies Corp. | 2 | \$91.6 | \$49.4 | Coal-fired high-performance power systems |
| M-C Power Corp. | 2 | \$87.7 | \$46.2 | Molten carbonate fuel cells |
| Air Products & Chemicals | 3 | \$58.1 | \$62.9 | Fuels and chemicals from synthetic gas |
| Riley Stoker Corp. ^b | 1 | \$44.3 | \$12.1 | Low-emission boiler systems |
| Combustion Engineering | 2 | \$31.3 | \$28.4 | Low-emission boiler systems |
| Fuel Cell Engineering Company | 1 | \$28.8 | \$24.8 | Molten carbonate fuel cells |

^aCompanies receiving awards from DOE may represent or lead teams of multiple contractors. In these cases, the lead company may divide the government's share of costs among team members.

^bRiley Stoker Corp., now called DB Riley, Inc., was competing with Combustion Engineering and Babcock and Wilcox Co. for the design and development of a low-emission boiler system. During September 1998, DOE selected DB Riley, Inc., over the other companies to continue the development of the technology.

Source: Developed by GAO using DOE's data.

⁴DOE also contracts for management of the National Institute for Petroleum Research in Bartlesville, Oklahoma, and the Pittsburgh Energy Technology Center. These contracts are valued at about \$215 million and \$97 million, respectively.

Appendix VI provides additional detail on both programs' awards that will cost the government more than \$1 million over the life of the project.

Agency Comments

We provided copies of a draft of this report to DOE for review and comment. We discussed the draft with DOE officials, including the Principal Deputy Assistant Secretary for Fossil Energy, who stated that the report effectively summarized the programs' goals, funding, and participants. DOE provided us with technical corrections and clarifications that we incorporated where appropriate.

Scope and Methodology

To identify the programs' goals and technologies, we interviewed officials in DOE's Office of Fossil Energy and reviewed documents such as the fiscal year 1998 budget request for the programs and the October 1997 update on the Clean Coal Technology Demonstration Program that discussed the program's goals and activities. To determine the programs' funding by R&D phrases and to identify the companies receiving these funds, we obtained detailed funding data for fiscal years 1996 through 1998 from DOE that identified the government's cost and total value of contracts active during this period and the companies receiving these procurement awards. We also interviewed DOE officials in the Office of Fossil Energy who compiled this funding information to discuss the assumptions that the officials used to prepare the information and its general reasonableness. However, we did not independently verify or validate the data provided to us.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 15 days after the date of this report. At that time, we will send copies to the Secretary of Energy and make copies available to others on request.

Please call me at (202) 512-3841 if you or your staff have any questions about this report. Major contributors to this report include Robin Nazzaro and Robert Lilly.

Sincerely yours,

A handwritten signature in cursive script, reading "Susan Kladiva".

Susan Kladiva
Associate Director
Energy, Resources, and Science Issues

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Abbreviations

| | |
|-----|--------------------------|
| DOE | Department of Energy |
| R&D | Research and Development |

Definitions of Research and Development Phases

Basic Research: Systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.

Applied Research: Systematic study to gain the knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.

Development: Systematic application of knowledge toward the production of useful materials, devices, and systems or methods, including the design, development, and improvement of prototypes and new processes to meet specific requirements.

Demonstration: Demonstration of advanced technologies to promote marketplace entry.

Source: Department of Energy (DOE).

DOE's Fossil Energy Research and Development Program's R&D Goals and Technologies by Budget Category

The following presents brief descriptions of the goals and technologies associated with DOE's Fossil Energy Research and Development (R&D) Program's R&D-related activities.

Advanced Clean Fuels Research

The overall goal of the Advanced Clean Fuels Research Subprogram within the Coal R&D Program is to develop technologies for producing clean coal and economically competitive coal-derived liquids. Table II.1 provides the specific goals and technologies by budget category.

Table II.1: Goals and Technologies Associated With the Activities Within the Advanced Clean Fuels Research Subprogram

| Budget category | Goals | New technological processes or planned areas of work |
|--|--|--|
| Coal preparation | Develop advanced technologies that remove minerals, sulfur, and potentially toxic material from coal before its use. | Biological, electrical, and chemical processes for separating impurities from coal and preparing the cleaned coal for final use. |
| Direct liquefaction | Develop commercially viable processes for converting coal into a liquid that can be used as a transportation or boiler fuel. | Processes that mix coal with water, oil, and/or petroleum-based wastes to generate a liquid fuel. |
| Indirect liquefaction | Develop commercially viable processes for converting coal into a liquid that can be used as a transportation or boiler fuel. | Processes that convert coal under high temperatures and/or pressures into a gas, which is then converted to a liquid fuel. |
| Advanced research and environmental technologies | Improve the information available on and explore new approaches that could reduce the costs of coal-derived liquids. | Applied research into the characterization of coal-derived liquids and the use of advanced catalysts for coal liquefaction. |

Source: DOE's FY 1998 Congressional Budget Request, Vol. 4, (Feb. 1997), pp. 39-44.

Appendix II
DOE's Fossil Energy Research and
Development Program's R&D Goals and
Technologies by Budget Category

Advanced Clean/Efficient Power Systems

The overall goal of the Advanced Clean/Efficient Power Systems Subprogram within the Coal R&D Program is to develop coal and natural gas-fired power plants that produce electricity more cheaply and with less environmental emissions than current power plants. Table II.2 provides the specific goals and technologies by budget category.

Table II.2: Goals and Technologies Associated With the Activities Within the Advanced Clean/Efficient Power Systems Subprogram

| Budget category | Goals | New technological processes or planned areas of work |
|--|--|--|
| Advanced pulverized coal-fired power plants | Improve current systems that burn pulverized coal to achieve efficiencies greater than or equal to 42% and emissions less than one-sixth of the New Source Performance Standards (NSPS). | Power plants called low emission boiler systems. |
| Indirect fired cycle | Develop more efficient combustion and heat transfer systems to achieve efficiencies greater than 45% and emissions less than one-tenth of NSPS. | High performance power plant systems that use high-temperature air furnaces integrating coal combustion and emission control requirements and combining gas turbines in the overall power plant. |
| High-efficiency integrated gasification combined cycle | Foster the commercialization of gasification-based processes that convert fossil resources to electricity and to steam, fuels, chemicals, or hydrogen. | Transport and fluid-bed gasifiers, sulfur sorbents; processes to remove particulates, nitrogen oxides, and toxic pollutants from gas streams; and concepts for cost effective carbon dioxide recovery. |
| High-efficiency pressurized fluidized bed | Improve the efficiency of existing fluidized-bed combustors that burn a mixture of coal particles and limestone under atmospheric pressure by combining a gasifier and gas turbine with pressurized equipment. | Processes to remove sulfur and other impurities from the hot gases without lowering the temperature of the gases. |
| Advanced research and environmental technologies | Develop insights into advanced coal gasification processes, the control of power plant emissions, and the disposal of power plant wastes. | More efficient and cost effective technologies to reduce carbon dioxide, sulfur dioxides, and other emissions from power plants. |

Source: DOE's FY 1998 Congressional Budget Request, Vol. 4, (Feb. 1997), pp. 45-55.

Appendix II
DOE's Fossil Energy Research and
Development Program's R&D Goals and
Technologies by Budget Category

Advanced Research and Technology Development

The overall goal of the Advanced Research and Technology Development Subprogram within the Coal R&D Program is to understand the fundamental scientific principles that govern coal combustion and environmental control processes and to support industry's efforts to expand coal exports. Table II.3 provides the specific goals and technologies by budget category.

Table II.3: Goals and Technologies Associated With the Activities Within the Advanced Research and Technology Development Subprogram

| Budget category | Goals | New technological processes or planned areas of work |
|--------------------------|---|--|
| Coal utilization science | Improve the knowledge available on the mechanisms involved in advanced coal combustion and the control of contaminants. | Mathematical models to predict the performance of advance combustion systems; research into advanced nitrogen oxide control and cleaning of high-temperature filters. |
| Technology crosscut | Develop better analyses of emissions from power plants, identify innovative technologies for using coal, and promote international cooperation and sharing of information on coal technologies and exports. | Mathematical analyses to predict emissions from advanced electric systems, studies to support multiyear planning, research into the potential for biotechnologies to be used to convert coal to other fuels, and maintaining relationships with international organizations. |
| University coal research | Support competitively awarded research grants to understand the science underlying coal combustion. | Research on a variety of chemical and engineering issues. |
| Materials and components | Develop materials that withstand the high temperatures and corrosive gases generated by advanced coal based power systems. | High temperature ceramics and filters, metal alloys, and components of fuel cells. |

Source: DOE's FY 1998 Congressional Budget Request, Vol. 4, (Feb. 1997), pp. 56-64.

Natural Gas Research

The overall goal of the Natural Gas Research Subprogram within the Gas Program is to ensure a long-term supply and the utilization of natural gas at reasonable prices by increasing the amount of gas that can be recovered, stored, delivered, and utilized in a clean, efficient manner. Table II.4 provides the specific goals and technologies by budget category.

Table II.4: Goals and Technologies Associated With the Activities Within the Natural Gas Research Subprogram

| Budget category | Goals | New technological processes or planned areas of work |
|----------------------------|--|--|
| Exploration and production | Develop advanced technologies for efficiently exploring and recovering gas from different types of fields. | Develop advanced drilling, completion, and stimulation systems. Develop reservoir data systems and imaging and modeling techniques. Assess the resource and develop techniques to produce gas from hydrates. |
| Delivery and storage | Improve the effectiveness and reduce the cost of current storage and delivery facilities and develop additional capacity to meet periods of high demand. | Inventory measurement systems, techniques to identify and prevent damage to wells used by underground storage facilities, and improved technologies for storing gas in salt formations. |
| Processing | Develop technologies to prepare for pipeline transportation and/or use of gas that is low in quality or found in remote locations. | Processes to minimize the corrosion of materials and to extract heat more efficiently through cooling combustion gases. |
| Turbines | Develop ultra-high-efficient natural gas turbines for electric power plants with the lowest emissions. | Utilization of advanced high-temperature materials and cooling technology, and advanced low-emission combustion systems. |
| Environmental | Develop credible and scientific information and advanced technologies to address high-priority environmental issues. | Risk assessments, new technology, impact analysis, and workshops to assess and remediate wastes and emissions from gas equipment and facilities. |

Source: DOE's FY 1998 Congressional Budget Request, Vol. 4, (Feb. 1997), pp. 65-74.

Fuel Cells

The overall goal of the Fuel Cells Subprogram within the Gas Program is to develop power plant technology for use in electric utility, on-site cogeneration, distributed generation, industrial, and commercial sectors that will be capable of ultra-high efficiencies and no harmful emissions. Table II.5 provides the specific goals and technologies by budget category.

Table II.5: Goals and Technologies Associated With the Activities Within the Fuel Cells Subprogram

| Budget category | Goals | New technological processes or planned areas of work |
|--|--|---|
| Advanced research | Identify processes and/or materials that will improve the efficiency and reduce the cost of fuel cell components. | Electrochemical processes and catalysts used for chemical conversions and improved ceramic materials and internal connections. |
| Molten carbonate fuel cells and solid oxide fuel cells (Formerly molten carbonate systems & advanced concepts) | Develop and demonstrate market entry fuel cell stationary power plant products; validate the economic and environmental benefits of molten carbonate and solid oxide technologies; promote the development of 70%-efficient fuel cell power plant designs. | Integration of components for proof-of-concept testing; customer tests of subscale integrated systems; and eventual commercial demonstration of full-scale systems. |

Source: DOE's FY 1998 Congressional Budget Request, Vol. 4, (Feb. 1997), pp. 75-78.

Oil Technology

The overall goal of the Oil Technology Subprogram within the Petroleum Program is to enhance the efficiency and environmental quality of domestic oil exploration, recovery, and processing. Table II.6 provides the specific goals and technologies by budget category.

Table II.6: Goals and Technologies Associated With the Activities Within the Oil Technology Subprogram

| Budget category | Goals | New technological processes or planned areas of work |
|---|---|--|
| Exploration and production supporting research | Develop technologies to locate and recover more oil from domestic reservoirs. | Imaging and diagnostic tools, techniques, and computer models to better locate oil and reservoir flow paths that control its production. Advanced extraction techniques using gas, heat, chemicals, or microbes to recover otherwise unproducible oil. |
| Recovery field demonstrations | Increase recovery from groups of known reservoirs with large volumes of remaining oil. Through demonstrations, transfer successful technologies to other oil operators. | Advanced and underutilized techniques for reservoir characterization, modeling, drilling, and extraction. |
| Exploration and production environmental research | Provide government and industry with information and science to address environmental concerns of oil and gas exploration and production. | Improved environmental compliance technologies; working with states and the federal government to streamline regulations; and the development of scientific and technical information for risk-based regulation. |
| Processing research and downstream operations | Increase the relative volume of high-quality transportation fuel that can be derived from heavy crude oils found in Alaska and California. | Cost-effective and environmentally acceptable heavy oil and residuum upgrading processing technologies. Provide scientific information for improved regulation. |

Source: DOE's FY 1998 Congressional Budget Request, Vol. 4, (Feb. 1997), pp. 79-91.

Cooperative Research and Development

The goal of the Cooperative R&D Program is to provide technical support to other programs in the Fossil Energy R&D Program. New technological processes or planned areas of work include support for research projects at (1) the University of North Dakota Energy and Environmental Research Center which provides scientific data on coal combustion to all R&D programs and (2) the Western Research Institute (WRI), which is the western center for oil and gas research. WRI provides information to the oil and gas programs on recovery and environmental issues.

There are no budget categories under this program.

Source: DOE's FY 1998 Congressional Budget Request, Vol. 4, (Feb. 1997), pp. 98-99.

Materials

The goal of the Materials Subprogram within the Mining R&D Program is to develop effective processes to produce advanced materials needed in the next generation of fossil fuel-fired power systems, solve environmental emissions problems related to fossil energy systems, determine the factors that limit the service life of materials and increase the cost of power generation in fossil fuel-fired power systems. New technological processes or planned areas of work include advanced casting technologies for high-temperature materials, sequestration of carbon dioxide through fixation as a carbonate mineral, advanced refractories technologies, and a database of information and a model to predict the erosion behavior of materials at elevated temperatures.

Source: DOE's FY 1998 Congressional Budget Request, Vol. 4 (Feb. 1997), pp. 105-110.

Fossil Energy R&D Funding by Phases of R&D, Fiscal Years 1996 Through 1998

Table III.1: Coal Program Funding, Fiscal Year 1996

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|--|-----------------------|-------------------------|--------------------|----------------------|
| Advanced Clean Fuels Research | | | | |
| Coal preparation | \$323 | \$2,351 | \$1,936 | 0 |
| Direct liquefaction | 383 | 2,797 | 2,304 | 0 |
| Indirect liquefaction | 401 | 2,922 | 2,406 | 0 |
| Advanced research and environmental technologies | 245 | 1,778 | 1,464 | 0 |
| Subtotal | \$1,352 | \$9,848 | \$8,110 | 0 |
| Advanced Clean/Efficient Power Systems | | | | |
| Advanced pulverized coal-fired power plants | \$740 | \$5,395 | \$4,443 | 0 |
| Indirect fired cycle | 838 | 6,105 | 5,028 | 0 |
| High-efficiency integrated gasification combined cycle | 1,011 | 11,009 | 9,566 | 0 |
| High-efficiency pressurized fluidized bed | 1,336 | 9,736 | 8,018 | 0 |
| Advanced Research and environmental technologies | 984 | 7,172 | 5,906 | 0 |
| Kalina cycle | 0 | 1,957 | 0 | 0 |
| Subtotal | \$4,909 | \$41,374 | \$32,961 | 0 |
| Advanced Research and Technology Development | | | | |
| Coal utilization science | \$3,120 | 0 | 0 | 0 |
| Technology crosscut | 3,716 | \$2,586 | 0 | 0 |
| University coal research | 4,865 | 0 | 0 | 0 |
| Materials and components | 4,750 | 2,035 | 0 | 0 |
| Subtotal | \$16,451 | \$4,621 | 0 | 0 |
| Total, Coal Program | \$22,712 | \$55,843 | \$41,071 | 0 |

Appendix III
Fossil Energy R&D Funding by Phases of
R&D, Fiscal Years 1996 Through 1998

Table III.2: Gas Program Funding, Fiscal Year 1996

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|-----------------------------------|-----------------------|-------------------------|--------------------|----------------------|
| Natural Gas Research | | | | |
| Exploration and production | \$1,112 | \$7,091 | \$5,702 | 0 |
| Delivery and storage | 85 | 536 | 430 | 0 |
| Turbines | 1,878 | 22,345 | 11,635 | 0 |
| Utilization | 377 | 2,402 | 1,929 | 0 |
| Environmental and regulatory | 233 | 1,489 | 1,197 | 0 |
| Subtotal | \$3,685 | \$33,863 | \$20,893 | 0 |
| Fuel Cells | | | | |
| Advanced research | \$103 | \$657 | \$529 | 0 |
| Molten carbonate systems | 1,472 | 21,945 | 13,729 | 0 |
| Advanced concepts | 2,047 | 6,529 | 5,249 | 0 |
| Subtotal | \$3,622 | \$29,131 | \$19,507 | 0 |
| Total, Gas Program | \$7,307 | \$62,994 | \$40,400 | 0 |

Table III.3: Petroleum Program Funding, Fiscal Year 1996

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|---|-----------------------|-------------------------|--------------------|----------------------|
| Oil Technology | | | | |
| Production supporting research | \$1,156 | \$17,226 | \$14,746 | 0 |
| Recovery field demonstrations | 542 | 5,637 | 4,661 | 0 |
| Exploration and production environmental research | 270 | 2,801 | 2,317 | 0 |
| Processing research and downstream operations | 279 | 2,582 | 2,718 | 0 |
| Total, Petroleum Program | \$2,247 | \$28,246 | \$24,442 | 0 |

Appendix III
Fossil Energy R&D Funding by Phases of
R&D, Fiscal Years 1996 Through 1998

Table III.4: Other Fossil R&D Funding, Fiscal Year 1996

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|--------------------------------------|-----------------------|-------------------------|--------------------|----------------------|
| Cooperative Research and Development | \$1,538 | \$1,538 | \$3,076 | 0 |
| Mining R&D | 4,998 | 0 | 0 | 0 |
| Total | \$6,536 | \$1,538 | \$3,076 | 0 |
| Total, Fossil Energy R&D | \$38,802 | \$148,621 | \$108,989 | 0 |

Appendix III
Fossil Energy R&D Funding by Phases of
R&D, Fiscal Years 1996 Through 1998

Table III.5: Coal Program Funding, Fiscal Year 1997

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|--|-----------------------|-------------------------|--------------------|----------------------|
| Advanced Clean Fuels | | | | |
| Coal preparation | \$340 | \$3,651 | \$1,108 | \$0 |
| Direct liquefaction | 423 | 3,755 | 879 | 0 |
| Indirect liquefaction | 475 | 2,047 | 1,730 | 0 |
| Advanced research and environmental technologies | 65 | 1,184 | 497 | 0 |
| Subtotal | \$1,303 | \$10,637 | \$4,214 | 0 |
| Advanced Clean/Efficient Power Systems | | | | |
| Advanced pulverized coal-fired power plant | \$570 | \$4,845 | \$4,585 | 0 |
| Indirect fired cycle | 600 | 6,103 | 3,802 | 0 |
| High-efficiency integrated gasification combined cycle | 1,350 | 11,475 | 9,675 | 0 |
| High-efficiency pressurized fluidized bed | 1,071 | 9,103 | 7,676 | 0 |
| Advanced research and environmental technologies | 565 | 5,801 | 3,048 | 0 |
| Kalina cycle | 0 | 0 | 0 | 0 |
| Subtotal | \$4,156 | \$37,327 | \$28,786 | 0 |
| Advanced Research and Technology Development | | | | |
| Coal utilization science | \$3,154 | 0 | 0 | 0 |
| Technology crosscut | 2,795 | \$2,463 | 0 | 0 |
| University coal research | 3,941 | 0 | 0 | 0 |
| Materials and components | 3,140 | 1,930 | 0 | 0 |
| Subtotal | \$13,030 | \$4,393 | 0 | 0 |
| Total, Coal Program | \$18,489 | \$52,357 | \$33,000 | 0 |

Appendix III
Fossil Energy R&D Funding by Phases of
R&D, Fiscal Years 1996 Through 1998

Table III.6: Gas Program Funding, Fiscal Year 1997

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|-----------------------------------|-----------------------|-------------------------|--------------------|----------------------|
| Natural Gas Research | | | | |
| Exploration and production | \$1,374 | \$7,264 | \$5,485 | 0 |
| Delivery and storage | 100 | 543 | 357 | 0 |
| Turbines | 3,750 | 28,606 | 16,244 | 0 |
| Utilization | 672 | 2,350 | 3,319 | 0 |
| Environmental and regulatory | 210 | 1,568 | 1,372 | 0 |
| Subtotal | \$6,106 | \$40,331 | \$26,777 | 0 |
| Fuel cells | | | | |
| Advanced research | \$130 | \$592 | \$496 | 0 |
| Molten carbonate systems | 2,547 | 19,557 | 15,295 | 0 |
| Advanced concepts | 1,585 | 6,280 | 4,635 | 0 |
| Subtotal | \$4,262 | \$26,429 | \$20,426 | 0 |
| Total, Gas Program | \$10,368 | \$66,760 | \$47,203 | 0 |

Table III.7: Petroleum Program Funding, Fiscal Year 1997

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|---|-----------------------|-------------------------|--------------------|----------------------|
| Oil Technology | | | | |
| Exploration and production supporting research | \$1,650 | \$17,464 | \$10,409 | 0 |
| Recovery field demonstrations | 412 | 3,511 | 1,973 | 0 |
| Exploration and production environmental research | 490 | 2,033 | 2,913 | 0 |
| Processing research and downstream operations | 524 | 2,994 | 1,903 | 0 |
| Total, Petroleum Program | \$3,076 | \$26,002 | \$17,198 | 0 |

Appendix III
Fossil Energy R&D Funding by Phases of
R&D, Fiscal Years 1996 Through 1998

Table III.8: Other Fossil Energy R&D Funding, Fiscal Year 1997

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|--------------------------------------|-----------------------|-------------------------|--------------------|----------------------|
| Cooperative Research and Development | \$1,391 | \$1,391 | \$2,784 | 0 |
| Mining R&D | 5,953 | 0 | 0 | 0 |
| Total | \$7,344 | \$1,391 | \$2,784 | 0 |
| Total, Fossil Energy R&D | \$37,886 | \$146,510 | \$100,185 | 0 |

**Appendix III
Fossil Energy R&D Funding by Phases of
R&D, Fiscal Years 1996 Through 1998**

Table III.9: Coal Program Funding, Fiscal Year 1998

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|--|-----------------------|-------------------------|--------------------|----------------------|
| Advanced Clean Fuels Research | | | | |
| Coal preparation | \$417 | \$3,312 | \$1,251 | 0 |
| Direct liquefaction | 579 | 3,927 | 1,092 | 0 |
| Indirect liquefaction | 481 | 2,287 | 1,762 | 0 |
| Advanced research and environmental technologies | 45 | 1,028 | 418 | 0 |
| Subtotal | \$1,522 | \$10,554 | \$4,523 | 0 |
| Advanced Clean/Efficient Power Systems | | | | |
| Advanced pulverized coal-fired power plant | \$328 | \$10,676 | \$2,678 | 0 |
| Indirect fired cycle | 656 | 2,497 | 4,198 | 0 |
| High-efficiency integrated gasification combined cycle | 2,458 | 12,147 | 7,617 | 0 |
| High-efficiency pressurized fluidized bed | 1,072 | 11,154 | 5,887 | 0 |
| Advanced research and environmental technologies | 584 | 8,566 | 3,186 | 0 |
| Kalina cycle | 0 | 391 | 0 | 0 |
| Subtotal | \$5,098 | \$45,431 | \$23,566 | 0 |
| Advanced Research and Technology Development | | | | |
| Coal utilization science | \$3,073 | 0 | 0 | 0 |
| Technology crosscut | 2,312 | \$960 | 0 | 0 |
| University coal research | 3,132 | 0 | 0 | 0 |
| Materials and components | 3,527 | 1,979 | 0 | 0 |
| Subtotal | \$12,044 | \$2,939 | 0 | 0 |
| Total, Coal Program | \$18,664 | \$58,924 | \$28,089 | \$0 |

Appendix III
Fossil Energy R&D Funding by Phases of
R&D, Fiscal Years 1996 Through 1998

Table III.10: Gas Program Funding, Fiscal Year 1998

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|-----------------------------------|-----------------------|-------------------------|--------------------|----------------------|
| Natural Gas Research | | | | |
| Exploration and production | \$1,489 | \$6,492 | \$5,984 | 0 |
| Delivery and storage | 99 | 519 | 388 | 0 |
| Turbines | 3,152 | 23,473 | 16,889 | 0 |
| Utilization | 481 | 3,439 | 2,875 | 0 |
| Environmental and regulatory | 462 | 611 | 2,001 | 0 |
| Subtotal | \$5,683 | \$34,534 | \$28,137 | 0 |
| Fuel Cells | | | | |
| Advanced research | \$133 | \$617 | \$560 | 0 |
| Molten carbonate systems | 0 | 0 | 0 | 0 |
| Advanced concepts | 0 | 0 | 0 | 0 |
| Fuel cell systems | 1,467 | 8,079 | 28,563 | 0 |
| Subtotal | \$1,600 | \$8,696 | \$29,123 | 0 |
| Total, Gas Program | \$7,283 | \$43,230 | \$57,260 | 0 |

Table III.11: Petroleum Program Funding, Fiscal Year 1998

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|---|-----------------------|-------------------------|--------------------|----------------------|
| Oil Technology | | | | |
| Exploration and production supporting research | \$946 | \$10,810 | \$19,155 | 0 |
| Recovery field demonstrations | 484 | 3,115 | 3,320 | 0 |
| Exploration and production environmental research | 513 | 2,484 | 2,988 | 0 |
| Processing research and downstream operations | 474 | 2,082 | 2,944 | 0 |
| Total, Petroleum Program | \$2,417 | \$18,491 | \$28,407 | 0 |

Appendix III
Fossil Energy R&D Funding by Phases of
R&D, Fiscal Years 1996 Through 1998

Table III.12: Other Fossil R&D Funding, Fiscal Year 1998

Dollars in thousands

| Subprogram/budget category | Basic research | Applied research | Development | Demonstration |
|--------------------------------------|-----------------------|-------------------------|--------------------|----------------------|
| Cooperative Research and Development | \$1,459 | \$1,463 | \$2,918 | 0 |
| Mining R&D | 4,965 | 0 | 0 | 0 |
| Total | \$6,424 | \$1,463 | \$2,918 | 0 |
| Total, Fossil Energy R&D | \$34,788 | \$122,108 | \$116,674 | 0 |

Clean Coal Technology Demonstration Program Funding, by Phases of R&D, Fiscal Years 1996 Through 1998

Table IV.1: Clean Coal Technology Demonstration Program Funding, Fiscal Year 1996

| Dollars in thousands | | | | |
|------------------------------------|-------------------|---------------------|-------------|-----------------|
| Subprogram/ budget category | Basic research | Applied research | Development | Demonstration |
| Clean Coal Technology | | | | |
| Advanced electric power generation | 0 | 0 | 0 | \$12,641 |
| Clean fuel | 0 | 0 | 0 | 0 |
| Environmental control devices | 0 | 0 | 0 | 16,721 |
| Industrial applications | 0 | 0 | 0 | 1,195 |
| Total | 0 | 0 | 0 | \$30,557 |

Table IV.2: Clean Coal Technology Demonstration Program Funding, Fiscal Year 1997

| Dollars in thousands | | | | |
|------------------------------------|-------------------|---------------------|-------------|------------------|
| Subprogram/ budget category | Basic research | Applied research | Development | Demonstration |
| Clean Coal Technology | | | | |
| Advanced electric power generation | 0 | 0 | 0 | \$103,168 |
| Clean fuel | 0 | 0 | 0 | 67,138 |
| Environmental control devices | 0 | 0 | 0 | 2,500 |
| Industrial applications | 0 | 0 | 0 | 9,403 |
| Total | 0 | 0 | 0 | \$182,209 |

Table IV.3: Clean Coal Technology Demonstration Program Funding, Fiscal Year 1998

| Dollars in thousands | | | | |
|------------------------------------|-------------------|---------------------|-------------|------------------|
| Subprogram/ budget category | Basic research | Applied research | Development | Demonstration |
| Clean Coal Technology | | | | |
| Advanced electric power generation | 0 | 0 | 0 | \$194,562 |
| Clean fuel | 0 | 0 | 0 | 9,510 |
| Environmental control devices | 0 | 0 | 0 | 0 |
| Industrial applications | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | \$204,072 |

Description of Non-R&D Fossil Energy Programs

Non-R&D programs pay for salaries and benefits, travel, the working capital fund for administrative services, and other non-R&D activities, including the following.

Environmental Restoration: Activities designed to protect workers and the public from exposure to hazardous conditions and material through the cleanup of R&D sites, site revegetation, and assessments/site investigations of inactive projects.

Coal Technology Export: Coal and technology export programs and promotion initiatives, trade mission assistance and other activities to promote the export of clean coal technologies, and the coordination of all fossil energy international crosscutting activities.¹

International Program Support: Analysis, studies, and technical evaluations of ongoing and planned bilateral and multilateral activities and support for international initiatives that leverage fossil energy resources. International involvements are limited to those selected areas where it has been determined that the United States will benefit at least to the extent it gives on a quid pro quo basis.

Historically Black Colleges and Universities, Education and Training: Training to accelerate workforce diversity in fossil fuel related technologies.

Plant and Capital Equipment: General plant projects at the Federal Energy Technology Center sites and the Bartlesville Project Office, including repairs, improvements, alterations, and additions.

Fuels Program: Processing of electricity export applications, participation in proceedings of the Federal Energy Regulatory Commission, and processing of natural gas import/export applications.

¹Coal technology export; international program support; and education and training activities at historically black colleges and universities are funded under DOE's coal R&D program.

Companies Receiving Fossil Energy R&D and Clean Coal Technology Demonstration Awards Over \$1 Million

Dollars in millions

| Awardee ^a | Description of award | Government share | Industry share | Total share |
|---|--|------------------|----------------|----------------|
| Westinghouse Electric Corp. | | | | |
| | Utility advanced turbines | \$119.1 | \$146.9 | \$266 |
| | High-temperature solid oxide fuel cell | 92.3 | 77.8 | 170.1 |
| | Solid oxide fuel cell | 82.9 | 115.5 | 198.4 |
| | Filter assessment | 2.1 | 0 | 2.1 |
| Subtotal | | \$296.4 | \$340.2 | \$636.6 |
| Wabash River Coal Gasification Repowering Project Joint Venture | Integrated gasification demonstration | 219.1 | 219.1 | 438.2 |
| City of Lakeland, Fla. | | | | |
| | McIntosh Unit 4B demonstration | \$109.2 | \$109.5 | \$218.7 |
| | McIntosh Unit 4A demonstration | 93.3 | 93.3 | 186.6 |
| Subtotal | | \$202.5 | \$202.8 | \$405.3 |
| Clean Energy Partners, L.P. | Combined fuel cell and gasification | 183.3 | 657.8 | 841.1 |
| Tampa Electric Co. | Integrated gas combined cycle | 171 | 172.5 | 343.5 |
| Sierra Pacific Power Co. | Integrated gas combined cycle | 168 | 167.9 | 335.9 |
| Air Products and Chemicals | | | | |
| | Liquid methanol process | \$92.7 | \$121 | \$213.7 |
| | Synthetic gas products | 28.6 | 7.1 | 35.7 |
| | ITM syngas technology | 25.6 | 54.8 | 80.4 |
| | Slurry bubble reactor | 3.9 | 1 | 4.9 |
| Subtotal | | \$150.8 | \$183.9 | \$334.7 |
| CPICOR Management Co., L.L.C. | Advanced iron-making process | 149.5 | 916.3 | 1065.8 |
| Foster Wheeler Development Corp. | High-performance system | 127.9 | 71.6 | 199.5 |
| General Electric Co. | | | | |
| | Utility advanced turbines | \$120 | \$263.7 | \$383.7 |
| | Advanced sorbent development | 1.1 | 0 | 1.1 |
| Subtotal | | \$121.1 | \$263.7 | \$384.8 |
| Alaska Industrial Development and Export Authority | Advanced combustor | 117.3 | 124.8 | 242.1 |

(continued)

Appendix VI
Companies Receiving Fossil Energy R&D
and Clean Coal Technology Demonstration
Awards Over \$1 Million

Dollars in millions

| Awardee^a | Description of award | Government share | Industry share | Total share |
|---------------------------------------|---|-------------------------|-----------------------|--------------------|
| Energy Research Corp. | Molten carbonate fuel cell | 101.7 | 39.7 | 141.4 |
| United Technologies Corp. | | | | |
| | High-performance system | \$89.4 | \$47.4 | \$136.8 |
| | Humid air turbine | 2.2 | 1.9 | 4.1 |
| Subtotal | | \$91.6 | \$49.3 | \$140.9 |
| M-C Power Corp. | | | | |
| | Molten carbonate fuel cell | \$71 | \$33.4 | \$104.4 |
| | Molten carbonate fuel cell | 16.7 | 12.8 | 29.5 |
| Subtotal | | \$87.7 | \$46.2 | \$133.9 |
| New York State Electric and Gas Corp. | | | | |
| | Milliken demonstration | \$72.2 | \$198.3 | \$270.5 |
| | Micronized coal reburning | 2.7 | 6.4 | 9.1 |
| Subtotal | | \$74.9 | \$204.7 | \$279.6 |
| York County Energy Partners | Atmospheric circulating fluidized bed | 74.7 | 304.9 | 379.6 |
| The Ohio Power Co. | Tidd pressurized fluidized-bed combustion demonstration | 67 | 122.9 | 189.9 |
| Pure Air on the Lake, L.P. | Advanced flue gas desulfurization | 63.9 | 87.8 | 151.7 |
| Babcock & Wilcox Co. | | | | |
| | Low-emission boiler systems | \$14.8 | \$3.6 | \$18.4 |
| | Emission control development | 5.3 | 6.5 | 11.8 |
| | Low-emission boiler system demonstration | 7.6 | 11.8 | 19.4 |
| | Coal reburning for nitrogen oxide control | 6.3 | 7.3 | 13.6 |
| | Flue gas cleanup demonstration | 6.1 | 7.2 | 13.3 |
| | Low nitrogen oxide cell burner retrofit | 5.4 | 5.8 | 11.2 |
| | Multiple pollutant removals | 2.6 | 1.2 | 3.8 |
| Subtotal | | \$48.1 | \$43.4 | \$91.5 |
| ENCOAL Corp. | Coal gasification demonstration | 45.3 | 45.4 | 90.7 |

(continued)

**Appendix VI
Companies Receiving Fossil Energy R&D
and Clean Coal Technology Demonstration
Awards Over \$1 Million**

Dollars in millions

| Awardee^a | Description of award | Government share | Industry share | Total share |
|---------------------------------|---|-------------------------|-----------------------|--------------------|
| NOXCO Corp. | Sulfur dioxide/nitrogen oxide removal demonstration | 42.8 | 43.3 | 86.1 |
| Riley Stoker Corp. | Low-emission boiler systems | 44.3 | 12.1 | 56.4 |
| Rosebud SynCoal Partnership | Coal cleaning and conversion | 43.1 | 62.6 | 105.7 |
| Southern Company Services | | | | |
| | CT-121 flue gas desulfurization | \$21.1 | \$22 | \$43.1 |
| | Selective catalytic reduction techniques | 9.4 | 13.8 | 23.2 |
| | Advanced wall-fired combustion | 6.6 | 9.3 | 15.9 |
| | Advanced tangentially fired combustion | 4.4 | 4.8 | 9.2 |
| Subtotal | | \$41.5 | \$49.9 | \$91.4 |
| Custom Coals International | Advanced coal-cleaning facilities | 38 | 49.4 | 87.4 |
| Combustion Engineering | | | | |
| | Low-emission boiler systems | \$32.2 | \$24.1 | \$56.3 |
| | Air toxics control | 1.6 | 0.8 | 2.4 |
| Subtotal | | \$33.8 | \$24.9 | \$58.7 |
| Bethlehem Steel Corp. | Granulated coal in blast furnace | 31.8 | 162.5 | 194.3 |
| Energy & Environmental Research | | | | |
| | Gas reburning and sorbent injection | \$18.7 | \$18.9 | \$37.6 |
| | Gas reburning and wall-fired burners | 8.9 | 8.9 | 17.8 |
| | Toxic emissions | 2.1 | 0 | 2.1 |
| | High-efficiency nitrogen oxide control | 1.6 | 0.7 | 2.3 |
| Subtotal | | \$31.3 | \$28.5 | \$59.8 |
| Fuel Cell Engineering Co. | Molten carbonate fuel cell | 28.8 | 24.8 | 53.6 |
| Hydrocarbon Technologies | | | | |
| | Proof-of-concept facility | \$21.9 | \$5.2 | \$27.1 |
| | Multistage liquefaction | 3.9 | 0.4 | 4.3 |
| | Bench-scale coprocessing | 2.7 | 0.2 | 2.9 |

(continued)

**Appendix VI
Companies Receiving Fossil Energy R&D
and Clean Coal Technology Demonstration
Awards Over \$1 Million**

Dollars in millions

| Awardee^a | Description of award | Government share | Industry share | Total share |
|--|-------------------------------------|-------------------------|-----------------------|--------------------|
| Subtotal | | \$28.5 | \$5.8 | \$34.3 |
| North Dakota University | | | | |
| | Low-rank coal (II) | \$12.7 | \$14.1 | \$26.8 |
| | Low-rank coal (I) | 11.7 | 0 | 11.7 |
| | Hybrid particulates collector | 1.3 | 0.3 | 1.6 |
| | Trace element emissions | 1.3 | 0 | 1.3 |
| Subtotal | | \$27 | \$14.4 | \$41.4 |
| Arthur D. Little Inc. | | | | |
| | Coal diesel combined cycle | \$23.8 | \$23.8 | \$47.6 |
| | Catalytic sulfur dioxide reduction | 1.5 | 0.3 | 1.8 |
| Subtotal | | \$25.3 | \$24.1 | \$49.4 |
| Western Research Inst. | | | | |
| | Joint projects | 13.1 | 18.3 | 31.4 |
| | Base research program | 7.5 | 0 | 7.5 |
| Subtotal | | \$20.6 | \$18.3 | \$38.9 |
| Clemson University | Advanced gas turbines | 19.6 | 1.6 | 21.2 |
| ThermoChem, Inc. | Steam gasification of coal | 18.7 | 18.6 | 37.3 |
| Tristate Generation and Transmission Assn. | Nucla fluidized bed demonstration | 17.1 | 29.4 | 46.5 |
| Public Service Co. of Colorado | | | | |
| | Integrated emission control | \$13.7 | \$13.7 | \$27.4 |
| | Mercury control | 2.2 | 0.5 | 2.7 |
| Subtotal | | \$15.9 | \$14.2 | \$30.1 |
| ABB Environmental Systems | SNOX flue gas cleaning | 15.7 | 15.7 | 31.4 |
| Amax R & D Inc. | Advanced fine coal cleaning | 13.6 | 1.7 | 15.3 |
| Radian Corp. | | | | |
| | Control of hazardous air pollutants | \$2.5 | \$1 | \$3.5 |
| | Clear liquor scrubbing | 2.4 | 1 | 3.4 |
| | Toxic emissions | 1.7 | 0 | 1.7 |
| Subtotal | | \$13.2 | \$4.0 | \$17.2 |
| Bechtel National Inc. | | | | |
| | Flue gas desulfurization | \$5.2 | \$5.2 | \$10.4 |
| | Refining coal liquids | 4.9 | 0 | 4.9 |

(continued)

**Appendix VI
Companies Receiving Fossil Energy R&D
and Clean Coal Technology Demonstration
Awards Over \$1 Million**

Dollars in millions

| Awardee^a | Description of award | Government share | Industry share | Total share |
|----------------------------------|---------------------------------------|-------------------------|-----------------------|--------------------|
| | Fischer-Tropsch technology | 2.9 | 0.1 | 3 |
| Subtotal | | \$13 | \$5.3 | \$18.3 |
| ABB Combustion Engineering Inc. | Coal evaluation software | 10.9 | 10.8 | 21.7 |
| LIFAC-North America | Sorbent injection desulfurization | 10.6 | 10.8 | 21.4 |
| Consortium for Fossil Fuels | Coal liquefaction | 9.9 | 8.5 | 18.4 |
| Hague International | Ceramic heater for turbines | 9.8 | 2.4 | 12.2 |
| Kentucky Research Foundation | | | | |
| | Coal liquefaction studies | \$6.6 | \$0 | \$6.6 |
| | Iron Fischer-Tropsch catalyst | 3.2 | 0 | 3.2 |
| Subtotal | | \$9.8 | \$0 | \$9.8 |
| University of Tenn. | MHD facilities completion | 9.4 | 0 | 9.4 |
| Phillips Petroleum Co. | | | | |
| | Carbon dioxide flood of oil reservoir | \$6.9 | \$14.3 | \$21.2 |
| | Sorbent development | 1.1 | 0 | 1.1 |
| Subtotal | | 8 | 14.3 | 22.3 |
| Strata Production Co. | Advanced oil recovery | 7.8 | 10.5 | 18.3 |
| Donlee Technologies Inc. | Cofiring of coal and wastes | 7.6 | 0.5 | 8.1 |
| Union Pacific Resources | Green River Basin | 7.3 | 4.4 | 11.7 |
| Dow Corning Corp. | | | | |
| | Methyl chloride from methane (II) | \$5.6 | \$10 | \$15.6 |
| | Methyl chloride from methane (I) | 1.4 | 1.4 | 2.8 |
| Subtotal | | \$7 | \$11.4 | \$18.4 |
| University of Oklahoma | Fluid characterization facility | 6.9 | 5.9 | 12.8 |
| ICF Resources Inc. | Systems analysis model | 6 | 0 | 6 |
| Passamaquoddy Tribe | Cement kiln flue gas recovery | 6 | 11.8 | 17.8 |
| Advanced Resources International | | | | |
| | Gas detection | \$3.5 | \$0.5 | \$4 |
| | Fracture stimulation | 1.9 | 0 | 1.9 |
| Subtotal | | \$5.4 | \$0.5 | \$5.9 |

(continued)

**Appendix VI
Companies Receiving Fossil Energy R&D
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Awards Over \$1 Million**

Dollars in millions

| Awardee^a | Description of award | Government share | Industry share | Total share |
|--------------------------------|---------------------------------------|-------------------------|-----------------------|--------------------|
| Parker and Parsley Development | Carbon dioxide gravity drainage | 5.2 | 8.0 | 13.2 |
| Stanford University | | | | |
| | Heavy oil recovery | \$2.1 | \$0 | \$2.1 |
| | Horizontal drilling | 2.1 | 0 | 2.1 |
| | Gas injection performance | 1 | 0.3 | 1.3 |
| Subtotal | | \$5.2 | \$0.3 | \$5.5 |
| Research Triangle Institute | | | | |
| | Hot gas desulfurization (bench-scale) | \$2.6 | \$0 | \$2.6 |
| | Acrylates and methacrylates | 1.3 | 0.4 | 1.7 |
| | Hot gas desulfurization concepts | 1.2 | 0 | 1.2 |
| Subtotal | | \$5.1 | \$0.4 | \$5.5 |
| CER Corp. | Field fracturing project | 4.8 | 4.7 | 9.5 |
| S. Powell Construction Co. | | | | |
| | Facility construction | \$3.7 | \$0 | \$3.7 |
| | Construction of syngas generator | 1 | 0 | 1 |
| Subtotal | | \$4.7 | \$0 | \$4.7 |
| Battelle Memorial Institute | | | | |
| | Toxics from coal | \$3.1 | \$0.1 | \$3.2 |
| | Characterization of air toxics | 1.4 | 0 | 1.4 |
| Subtotal | | \$4.5 | \$0.1 | \$4.6 |
| BPF Inc. | Development of norm | 4.3 | 0 | 4.3 |
| Maurer Engineering Inc. | | | | |
| | Tubing drilling system | \$3 | \$1.9 | \$4.9 |
| | Underbalanced drilling products | 1 | 0.2 | 1.2 |
| Subtotal | | \$4 | \$2.1 | \$6.1 |

(continued)

Appendix VI
Companies Receiving Fossil Energy R&D
and Clean Coal Technology Demonstration
Awards Over \$1 Million

Dollars in millions

| Awardee^a | Description of award | Government share | Industry share | Total share |
|--------------------------------------|--|-------------------------|-----------------------|--------------------|
| Atlantic Richfield Co. | Oil recovery techniques | 4.0 | 3.9 | 7.9 |
| ABB Power Generation | Turbine research | 3.6 | 0.9 | 4.5 |
| Physical Sciences Inc. | Toxics from coal | 3.4 | 0.9 | 4.3 |
| Electric Power Research Institute | | | | |
| | High sulfur test facility | \$2 | \$8.5 | \$10.5 |
| | Utility biomass cofiring | 1.4 | 4 | 5.4 |
| Subtotal | | \$3.4 | \$12.5 | \$15.9 |
| Coleman Research Corp. | Gas detection | 3.3 | 0 | 3.3 |
| Energy & Environmental Analysis | Gas information system | 3.2 | 0 | 3.2 |
| Virginia Polytech Institute | | | | |
| | Hazardous air pollutant precursors removal | \$1.6 | \$0.4 | \$2 |
| | Testing of coal separator | 1.3 | 0.4 | 1.7 |
| Subtotal | | \$2.9 | \$0.8 | \$3.7 |
| Gas Technology Information Institute | International center for gas | 2.7 | 0 | 2.7 |
| Roy Weston Inc. | Toxic emissions | 2.7 | 0.1 | 2.8 |
| Carnegie-Mellon University | | | | |
| | Coal gasification systems | \$1.4 | \$0 | \$1.4 |
| | Environmental control model | 1.3 | 0 | 1.3 |
| Subtotal | | \$2.7 | \$0 | \$2.7 |
| The M. W. Kellogg Co. | Hot gas desulfurization facility | 2.5 | 0 | 2.5 |
| AirPol, Inc. | Gas suspension absorption | 2.3 | 5.4 | 7.7 |
| Novatek | Mud drilling system | 2.3 | 1 | 3.3 |
| Southern Research Institute | Hot gas cleanup | 2.2 | 0 | 2.2 |
| University of Utah | Increased heavy oil recovery | 2.2 | 3.6 | 5.8 |
| Southern Illinois University | Desulfurization products | 2.1 | 1.1 | 3.2 |
| Pacific Operators Offshore | Class III oil recovery | 2 | 2.2 | 4.2 |
| Smith International | Steerable air percussion | 2 | 1.1 | 3.1 |
| Hughes Eastern Corp. | Using microflora near oil formation | 1.9 | 2 | 3.9 |
| James Bunger & Associates | Shale oil enhancement | 1.9 | 0 | 1.9 |
| CQ Inc. | Hazardous air pollutant removal | 1.8 | 0.7 | 2.5 |

(continued)

**Appendix VI
Companies Receiving Fossil Energy R&D
and Clean Coal Technology Demonstration
Awards Over \$1 Million**

Dollars in millions

| Awardee^a | Description of award | Government share | Industry share | Total share |
|-----------------------------------|--------------------------------|-------------------------|-----------------------|--------------------|
| Consolidated Coal Co. | Coal liquefaction | 2.5 | 0 | 2.5 |
| Tulane University | US/China technology center | 1.8 | 0 | 1.8 |
| Advanced Technology Systems | Sampling and analyzing methods | 1.7 | 0 | 1.7 |
| Gas Technology Institute | Evaluation of contractors | 1.7 | 3.2 | 4.9 |
| Department of Interior | U.S. Geological Survey studies | 1.7 | 0 | 1.7 |
| ADA Technologies Inc. | Mercury vapor removal | 1.6 | 0.3 | 1.9 |
| Flowdril Corp. | Slim-hole high pressure pump | 1.6 | 2.4 | 4 |
| LSR Technologies | Particulate air toxic control | 1.6 | 0.7 | 2.3 |
| Sperry-Sun Drilling | Underbalanced drilling | 1.6 | 0.7 | 2.3 |
| Tempress Technologies | Hydraulic pulse drilling | 1.6 | 0.9 | 2.5 |
| University of Kansas | Improved oil recovery | 1.6 | 1.6 | 3.2 |
| American Geological Institute | National data system | 1.5 | 0.4 | 1.9 |
| Interstate Oil Compact | State regulations | 1.5 | 0.4 | 1.9 |
| Mitre Corp. | Research guidance studies | 1.5 | 0 | 1.5 |
| Petroleum Consulting | CO2/sand fracturing | 1.5 | 0 | 1.5 |
| West Virginia University Research | Ash disposal in mines | 1.5 | 0.6 | 2.1 |
| Advanced Fuel Research | Fossil fuel conversion | 1.4 | 0 | 1.4 |
| State of Oklahoma | Data management system | 1.4 | 0 | 1.4 |
| Conoco Coal Development | Coal liquefaction concept | 1.3 | 0.3 | 1.6 |
| Dravolime Co. | Dry FGD by-products | 1.3 | 3 | 4.3 |
| Pennsylvania State University | Coal sample bank and database | 1.3 | 0 | 1.3 |
| Texas Railroad Commission | Data management systems | 1.2 | 0 | 1.2 |

(continued)

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Companies Receiving Fossil Energy R&D
and Clean Coal Technology Demonstration
Awards Over \$1 Million

Dollars in millions

| Awardee^a | Description of award | Government share | Industry share | Total share |
|----------------------------|---|-------------------------|-----------------------|--------------------|
| University of Wyoming | Riverton dome demonstration | 1.2 | 1.7 | 2.9 |
| Fisher-Klosterman, Inc. | Coal reactors | 1.1 | 0 | 1.1 |
| Michigan Technologies | Dundee foundation oil recovery | 1.1 | 1.6 | 2.7 |
| Little Bear Lab Inc. | Removal of hazardous air pollutant precursors | 1 | 0.3 | 1.3 |
| Underground Injection Co. | Implement data system | 1 | 0 | 1 |

^aCompanies receiving awards from DOE may represent or lead teams of multiple contractors. In these cases, the lead company may divide the government's share of costs among team members.